Session 1 – Modelling the Universe

General Description

Students are challenged to create a model of the Universe. This is an introductory activity that helps students think about where we fit in the Universe, and allows them to model the size, shape, and relative position of objects in the Universe. The activity has three major steps: discussion, modelling, and sharing models with the group. Students work in groups of 3 or 4.

Objectives

- To improve students' understanding of the current scientific model for the structure of the Universe and the evidence that supports that model.
- To use the context of space science exploration of the structure of the Universe to help students reflect on the nature of models, evidence, and explanation in science.

Concepts Addressed

- Earth's physical place in the solar system and Universe
- Astronomical size and scale
- Strengths and weaknesses of models

Materials

- Copy of Universe Model Analysis Student Worksheet for each group of students (included)
- Examples of models (toy car, doll or action figure, paper airplane, map, etc.)
- A variety of crayons/colored pencils/markers
- 8.5 by 11" white paper – one sheet per student
- Model construction supplies – anything you have available that seems appropriate. Some examples: construction paper, balloons, balls of different sizes, marbles, string, straws, pipe cleaners, pasta
- Large sheet of sturdy paper on which students create their models – one per group
- Scissors, glue, and tape

Other Requirements

- Enough table or floor space for several groups of students to work together on their models

Background

Less than a century ago, astronomers thought our galaxy of stars might be the whole Universe. Today, we know that our galaxy is only one of billions of galaxies. Astronomers now study galaxies far beyond our own Milky Way. About 100 billion galaxies make up our "observable Universe."

A model is a simplified imitation of something that is used to better understand or work with it. Models can take different forms, including physical devices or sculpture, drawings or plans, conceptual analogies, mathematical equations, and computer simulations.

Models serve many different purposes in astronomy and other fields. A model can make something large more portable and accessible, such as representing the Earth with a tabletop globe. Models can also make something small easier to see and manipulate, such as a model of a tiny cell or DNA. And some models are the same size as the original object, often used for testing or display purposes.

Models can be "to scale," which means that they accurately represent the proportions of an actual object. The scale model can be smaller, larger, or the same size as the original object, but the proportions must be accurate. Some models are not to scale, and do not accurately reflect the actual proportions of the original. These models can be useful when it is difficult to create a scale model, or an accurate scale model is not needed.

Session overview

As a warm-up, students make a quick model (drawing) of something in their lives. This introduces the concept of modelling.

Students make physical models to represent as much of the Universe as they can. They then analyze their own and others' models with regard to what they represent, what they misrepresent, what they omit, and what questions they raise.

While the idea of creating a physical model of the entire Universe can seem overwhelming, this activity quickly reveals students' ideas and preconceptions. Most students are somewhat familiar with solar system objects but may be confused about, for example, the relationship of stars to planets and the relative distances between them. The overall organization and structure of the Universe is not well known to most.

Students should not be corrected in any way during this session, as this is intended to determine the current state of their understanding for later evaluation.

Preparation

- Make copies of the Universe Model Analysis Student Worksheet for each group
- Set out all listed materials equally among the groups

Activity

(Adapted with permission from the Cosmic Questions Educator's Guide available at *http://cfa-www.harvard.edu/seuforum/learningresources.htm*)

I. Warm-up (10 minutes)

Instruct students to individually draw a quick model of something in their lives, using the white paper and crayons/colored pencils/markers available. Allow about five minutes for students to complete these drawings.

Ask students to identify some models in their lives, such as toy cars, dolls and action figures, models made for school assignments, model airplanes, maps, etc. It is helpful to have a couple of these examples to show during this discussion. Introduce the idea of scale – models that accurately reflect the proportions of the original object. Are the models you have discussed to scale or not to scale?

Ask a few students to share their warm-up drawings. Are these models to scale or not to scale? Tell students to keep these ideas about models and scale in mind during the next activity.

II. Discussion (10 minutes)

Lead an open discussion about what is IN the Universe, and what the Universe IS.

Have students brainstorm a list of objects in the Universe that can be viewed with a telescope, and ask what they know about each one as they are offered. Write these objects on a blackboard or flipchart.

"What do you think is in the Universe?"
"What is a planet / star / galaxy / other? What do you know about planets / stars / galaxies / other objects?"
"What do you think these objects look like through a telescope?"
"Which ones can we see without a telescope?"

Facilitate a group discussion of what models are and what they are used for. Discuss how scientists use models to help them think about how things work, and to make predictions. Ask

students to name some familiar models (ex. globe, dollhouse) and lead a discussion on whether these models are exactly like the real thing. Stress that a model is not the real thing, it is usually a simplified version so it can always misrepresent features of the real thing.

III. Modelling (20 minutes)

Divide students into groups of 3 or 4. Groups should decide among themselves who will fill the roles of Model Maker, Recorder of Model Features, and Spokesperson. Students may have more than one role, but all three must be filled.

Ask the students to write their names on both the model they create and their worksheet.

With the materials in front of them, challenge students to create a model of the Universe in 20 minutes.

Tell students they should have an explanation as to why they put objects where they do, regardless of the fact that **they are not required or expected to have all of the scientifically correct answers!**

As they work, the Recorder in each group should use the Universe Model Analysis Student Worksheet to list information about the features of their model, and any questions or other thoughts that arise on this topic.

IV. Sharing models with the group (15-20 minutes)

Now, ask the spokesperson in each group to present their model. As they do so, ask them to comment on these four questions:

➢ *What features of the Universe does your model represent?*
➢ *What things – that you know of – does your model misrepresent?*
➢ *What things – that you know of – does your model omit, or not represent at all?*
➢ *What questions came up as your group worked on your model?*

Use the following questions with the whole group to further probe students' understanding of their models:

➢ *Do you see any patterns?*
➢ *Which parts of the models do you think represent the "real thing" particularly well? Why?*
➢ *Which parts of the models do you think misrepresented the "real thing"?*
➢ *Are these models to scale or not to scale? Why?*
➢ *Why is making a model of the whole Universe so difficult?*
➢ *How can these models be used to predict what might happen in the Universe?*
➢ *What would an observer on Earth see if they lived in this Universe?(find Earth first)*
➢ *What would you need to know to design a better model?*

At the end of the activity, *collect and save the worksheets (or take a digital photo of them).* They will be used in concert with the final session to evaluate student progress.

Suggestions/Misconceptions

- Allow students to take over as much of the discussions as possible, trying not to lead or discourage them in any way. Also, make sure that students understand that there has to be a reason for where they place objects when they created their model.

- Although modelling the Universe is the best way to increase understanding and find misconceptions, you may wish to have some groups choose just a part of the Universe to model - such as the solar system, or a galaxy, or the Earth-Moon system - if you feel that modelling the entire Universe would be too much of a burden for them.

- The materials provided for this activity often have an impact on the models made by students. For consistency, provide the same materials in Session 1 and the repeated modelling activity in Session 12.

Useful websites for background or activity extension

- **NASA's Universe Education Forum**
  - *Answers to questions about the structure and evolution of the Universe are available at this site*
    http://www.Universeforum.org/questions/
  - *Extensive learning resources for investigations of the Universe*
    http://www.cfa.harvard.edu/seuforum/learningresources.htm

- **Cosmic Distance Scale**
  This feature gives a feeling for how immense our Universe is, starting with an image of the Earth and then zooming out to the furthest visible reaches of our Universe –as in the "Power of 10" films.
  http://heasarc.gsfc.nasa.gov/docs/cosmic/cosmic.html

- **Bad Astronomy – Astronomy misconceptions explained**
  A great site to deal with questions about the accuracy of "science" encountered in the movies, news, books, or TV. In addition to science explanations at an easy-to-read level, topics are presented in a fun way. The site contains a blog and a bulletin board for questions.
  http://www.badastronomy.com

Afterschool Universe Session 1 – Universe Model Analysis Student Worksheet

Date: _____   Name: _____

A model is a simplified imitation of something designed to help us understand it better. It may represent the whole or only part of a system. Because a model is not the real thing, it can always misrepresent some features of the real thing.

As you create your model of the Universe, you should have an explanation for why you are doing something. It is completely ok if are taking a guess – but you should explain why you guessed that way.

You will be asked to explain your model to the rest of the class, commenting on these questions:

❖ What features of the universe does your model represent?

❖ What things does your model not represent well?

❖ What things about the universe does your model leave out, or not represent at all?

❖ What questions came up as your group worked on your model?

Features represented	Misrepresented features	Features omitted by model

Questions we had

Session 8 – Our Cosmic Connection to the Elements

General Description

An interactive discussion of elements and compounds begins with the leader and class breaking down a substance into smaller and smaller pieces that still retain its identity. The discussion continues with the periodic table, common elements and compounds, and the astronomical origin of the elements we are made of. Students determine the composition of a sample of "space particles" and discuss the difficulties of finding a truly representative sample. They view printed elemental spectra and discuss how astronomers determine the composition of distant objects (reinforces Session 4 on spectroscopy).

Objectives

- To explore the concept of composition in the context of the Universe and astronomical objects.
- To improve students' understanding of the origin of the chemical elements.

Concepts Addressed

- Elements and compounds
- Composition of the Universe
- Spectroscopy

Materials

- One pound cake – choose one with the fewest artificial ingredients (don't substitute with a different kind of cake, as it must be a dense cake that doesn't fall apart when cut)
- Knife to cut the cake
- Enough paper plates to hold pieces of cake as it is cut (enough to serve the class, if allowed)
- Sample of a pure element (piece of copper tubing works well)
- Periodic table, one copy per student (included)*

- *Cosmic Connection to the Elements* poster (included)
- Universe Trail mix ingredients (see Universe Trail Mix Procedure for amounts): rice, split peas, macaroni, black beans, pink beans, and colored sprinkles
- Large bowl to mix the trail mix
- Small paper cups or bowls, one per student
- Paper towels, one sheet per student
- Plastic spoons (only one is required, but have extras on hand)
- Universe Trail Mix key (provided)*
- Universe Trail Mix worksheet (provided)
- Handouts with elemental spectra (provided)*
- Paper to write on, 1 sheet per student

* You can laminate these handouts if you want to use them with other groups. You only need to hand out one of these sheets per group of students.

Other Requirements

- A room with sufficient space for students to spread out and count their "elements"
- Access to a blackboard or flip chart is advised

Background

Atom: The smallest particle of an element that still has the characteristics of that element

Element: A *material* consisting of all the same atoms

Molecule: Two or more atoms of the same or different elements that are chemically bound together

Compound: A *material* consisting of atoms of two or more different elements that are chemically bound together

The copper/other pure element used here is an element, while the pound cake is a compound since it is made of many different substances (or elements).

We are made of star stuff!

The lightest elements (hydrogen, helium, and some lithium) were created in the Big Bang.

Then as the Universe cooled, matter clumped together to form stars. In the stars, those first elements were fused into heavier ones by the energy from the stars' gravity – up to a certain point.

The formation of elements heavier than iron and lead requires more energy than a star has. But the explosion of a star at the end of its life (a supernova) provides enough energy to go much further down the periodic table. A supernova throws all of its elements out into space, where new stars can use them as they form.

We know the Sun is a later-generation star because it has those heavier elements (we know that from spectroscopy, among other ways). So the elements in our bodies - like carbon, hydrogen, nitrogen, oxygen, and trace amounts of many others - came from the explosion of earlier stars!

Session overview

An interactive discussion of elements and compounds begins with the leader and class breaking down a substance (pound cake) into smaller and smaller pieces that still retain its identity (its "atoms").

The discussion continues with the periodic table, common elements and compounds, and the astronomical origin of the elements we are made of. Students take a sample of "space particles in the Universe" (a prepared mixture of rice, beans, etc.), determine its composition, and discuss the difficulties of finding a truly representative sample.

Students view a chart of spectra matched with the elements that produce them, and they discuss how astronomers determine the composition of distant objects (reinforces Session 4 on spectroscopy).

Preparation

- This takes a bit of time, so <u>prepare this mixture at least a few hours before the Universe Trail Mix activity</u>:

  Using the recipe below, measure the ingredients into a large bowl and mix well. Use the same size "measuring cup" (a plastic spoon) for all of the ingredients.

  - 40 spoonfuls of rice (to represent 89% abundance of hydrogen in Universe)
  - 4 spoonfuls of split peas (to represent 9% abundance of helium)
  - 2 spoonfuls of macaroni (to represent 0.75% abundance of carbon)
  - 2 spoonfuls of black beans (to represent 0.75% abundance of oxygen)
  - 1 spoonful of pink beans (to represent 0.25% abundance of nitrogen)
  - 1 spoonful of sprinkles (to represent 0.25% abundance of all other elements)

  The amounts of macaroni, black beans, pink beans, and sprinkles are highly exaggerated, because they would not be visible in the mixture in smaller amounts.

- Laminate handouts if desired.

- Have the pound cake and knife ready. Wash your hands before handling the pound cake, if it is to be consumed after use. Save the ingredient label.

Activity

I. Poundcakium activity (15-20 minutes)

1. Tell the group that the calcium and iron - and many other elements - in our bodies were created in a star that exploded. In fact, all of the elements originated well outside our solar system. Elicit student thoughts about this. (Don't explain any of it yet.)

   Hold up the pound cake. *What is this?*

   Let's pretend that we just discovered this dessert, called "Poundcakium." What are some of its characteristics? Let them answer. Answers should include that it's all one flavor, texture, and color. Cut the cake in half.

   What do we have now? Will it taste the same. Yes – so it is the same thing we had before. Still poundcakium, but in two pieces. Cut it in half again.

   What do we have now? Still poundcakium.

   If we continue to cut it in half, we eventually get to single crumbs. Have we destroyed or created any poundcakium as we did this? Did it become something else other than poundcakium by cutting it? No.

   If allowed, serve the pound cake! You can continue while students munch.

2. *Many things are made of more than one ingredient. What do you think the ingredients are in the poundcakium?* Let them answer, then read through the pronounceable ingredients on the label.

   But the flour, sugar, milk and eggs [or whatever the recognizable ingredients are] *are made of elements like carbon and hydrogen.*

   Put up the Cosmic Elements poster and point out carbon and hydrogen.

   An element is a material made of atoms of a single type, like carbon or hydrogen. Elements are the building blocks for matter - everything that we can see and touch.

   Hold up your pure element. (For illustration here, we will say we are using the piece of copper tubing. You can also use other examples of pure elements if you have them readily available.)

Copper is an element that occurs naturally on Earth.

Copper is very hard to cut, but we could do the same thing we did with poundcakium. If we cut the copper in half, would it be a different substance? No, it's still the same thing, and the weight is still the same. Since copper is an element, no matter how many times it's cut it in half, we will always have copper.

3. Going back to the poster… *All of the known elements have been organized into this Periodic Table of the Elements. It is arranged so that the elements in the same rows and columns have common characteristics, though each remains unique. Some are solids, some are gases, and some are liquids, for example.*

   Pass out the individual periodic tables.

   Do you recognize any of the elements? Can you give me an example of an everyday object, and the element that it's made of? (examples: aluminum in soda cans, silver/gold in jewelry, diamonds (carbon), iron in steel, hydrogen and oxygen in water - "lead in pencils" should be corrected to "carbon (in the form of graphite) in pencils".)

   Some common substances like table salt (NaCl – sodium chloride) or water (H_2O) are compounds, which are made of two or more elements chemically bound together.

   Is <u>poundcakium</u> an element or a compound? (wait for guesses with explanations) It pretends to be an element for our purposes

   Is the <u>pound cake</u> an element or compound? (wait for guesses with explanations) A compound

4. *What are we (people) made of?* (wait for guesses with explanations) We're made of a lot of the elements on the periodic table, many in the form of compounds like water.

   Where do you think these elements came from? Wait for ideas.

   The lightest elements (hydrogen, helium, some lithium) were created in the Big Bang.

   Then as the Universe cooled, matter clumped together to form stars. In the stars, those first elements were fused into heavier ones by the energy from the stars' gravity – up to a certain point.

   The formation of elements heavier than iron and lead requires more energy than a star has. But the explosion of a star at the end of its life (a supernova) provides enough energy to go much further down the periodic table. A supernova throws all of its elements out into space, where new stars can use them as they form.

   We know the Sun must have formed from material that was enriched by a supernova explosion because it has small amounts of heavier elements (we know that from spectroscopy, among other ways). So the elements in our bodies - like carbon, hydrogen,

nitrogen, oxygen, and trace amounts of many others - came from the explosion of earlier stars!

We are made of star stuff!

II. *Universe Trail Mix activity (15-20 minutes)*

Before beginning this activity, everyone should finish eating if they were doing so. Remove all traces of remaining pound cake – to avoid distraction.

Distribute the Universe Trail Mix worksheets, the Universe Trail Mix keys (so that they know which ingredient represents which element), small cups, and sheets of paper towel.

Ask the group: *What element do we have the most of in the Universe? If we grabbed a handful of space particles, what would we have?* Wait for guesses.

Pull out the trail mix and plastic spoon to serve it.

This trail mix was prepared to imitate the proportions of the most common elements in the Universe.

Have each student take a spoonful of the mix and put it in a cup. Back in their own workspace, they empty it onto the paper towel. Students then count or estimate how much of each ingredient (element) they have, and record it on their worksheet.

When all have finished, ask how many of them found hydrogen? helium? carbon? They should all have mostly hydrogen, some helium, and very few of the others.

Ask how many of them had any oxygen, nitrogen, or sprinkles (which represent small amounts of other elements). Note that these are rare and not found in every spoonful.

On a blackboard or flip chart, set up a table with a column heading for each element. Have each student come up and record how much of each "element" they found. Have two volunteers come up and tally the entries to arrive at total for each element (having two volunteers should verify the addition).

With prompting as needed, students should discuss the *relative* amounts of the elements.

Why did some of the elements not appear in all of the samples? Do you think this would be similar to when we look out into space? That is, if we looked at one region in space near a star, do you think we would find the same sorts of elements as if we looked where there no stars? The answer is no – where we look is very important and tells us what that region is made of.

Have everyone look at a periodic table again, and go through the true percentages of elements in the Universe: Almost 90% of the Universe is hydrogen, and more than 9% is helium. The rest of the elements add up to less than 1%, but that 1% includes **all** of the heavier elements that are out there.

III. Follow-up discussion (10-15 minutes)

You just used spoonfuls of the Universe Trail Mix to try to figure out what the Universe is made of. But you can't get a spoonful of things in space, since they are so far away. We have to figure out what they are made of without touching them. We can do this with light.

Remind students about the Session 5 activity on spectroscopy, if they did it - to recap:

> One way you can tell what an object is made of is to look at its spectrum. A spectrum is like an element's fingerprint. Each element produces a unique pattern of specific wavelengths of light, which we see as bright lines in the spectrum. A scientist looking at the spectrum of an object in space, like a star or planet, can figure out which elements are in that object by looking at the different lines in its spectrum –they use spectroscopy.

Hand out papers with the spectra of different elements.

What do you see? Wait for ideas.

It looks like a faint rainbow, with some bright lines here and there. Have them look at the spectrum for hydrogen, and discuss where the bright lines are.

Have them look at the spectrum for helium. Discuss where the bright lines are, and compare this spectrum to the spectrum for hydrogen.

If you would like to see spectra for more elements, as well as for white light, go to the University of Colorado Physics 2000 site:

http://www.colorado.edu/physics/PhysicsInitiative/Physics2000/quantumzone/

So when astronomers look out into space and study the spectra of objects, they can figure out which elements are present from the lines they are seeing. Each element has a unique spectrum and how bright or faint it is tells us how much of that element is present.

Suggestions/Misconceptions

- If dark matter comes up, explain that we still don't know exactly what it is, and we are only talking about normal matter in these activities.

Useful websites for background or activity extension

- **Los Alamos National Laboratory**
  Great interactive periodic table, with much information about each element
  http://periodic.lanl.gov/

- ***Imagine the Universe!***
  - *Extended activity about composition using beans and rice, with bottles full of objects on Earth and space:*
    http://imagine.gsfc.nasa.gov/docs/teachers/elements/imagine/OutThere/outthere.html
  - *Good explanations of the electromagnetic spectrum and spectroscopy:*
    http://imagine.gsfc.nasa.gov/docs/teachers/lessons/xray_spectra/background-spectroscopy.html
  - *Lesson plan at high school level on the origin of the elements and our connection to them:*
    http://imagine.gsfc.nasa.gov/docs/teachers/elements/elements.html
  - *High-school level activity and discussion of the formation of elements in stars and their release in supernovae:*
    http://imagine.gsfc.nasa.gov/docs/teachers/calcium/calcium_intro.html

PERIODIC TABLE
Atomic Properties of the Elements

Legend:
- Solids (white)
- Liquids (blue)
- Gases (pink)
- Artificially Prepared (yellow)

Key:
- 58 — Atomic Number
- Ce — Symbol
- Cerium — Name

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen																	2 He Helium
2	3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
3	11 Na Sodium	12 Mg Magnesium											13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
4	19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
5	37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
6	55 Cs Cesium	56 Ba Barium	57 La Lanthanum	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
7	87 Fr Francium	88 Ra Radium	89 Ac Actinium	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Uun Ununnilium	111 Uuu Unununium	112 Uub Ununbium		114 Uuq Ununquadium		116 Uuh Ununhexium		

Lanthanides

58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium

Actinides

90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Universe Trail Mix

Black Beans = Oxygen (O)

Blue Sprinkles = Magnesium (Mg)

Green Split Peas = Helium (He)

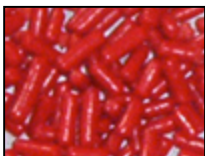Macaroni = Carbon (C)

Orange Sprinkles = Silicon (Si)

Green Sprinkles = Neon (Ne)

Pink Beans = Nitrogen (N)

Rice = Hydrogen (H)

Red Sprinkles = Iron (Fe)

Yellow Sprinkles = Sulfur (S)

Universe Trail Mix Worksheet

INGREDIENT	ELEMENT	HOW MANY?
Black Beans	_____	_____
Blue Sprinkles	_____	_____
Green Split Peas	_____	_____
Macaroni	_____	_____
Orange Sprinkles	_____	_____
Green Sprinkles	_____	_____
Pink Beans	_____	_____
Rice	_____	_____
Red Sprinkles	_____	_____
Yellow Sprinkles	_____	_____

1. Which element is the most abundant? _____

2. Which element is the second most abundant? _____

3. Did you find all of the elements in your sample? _____

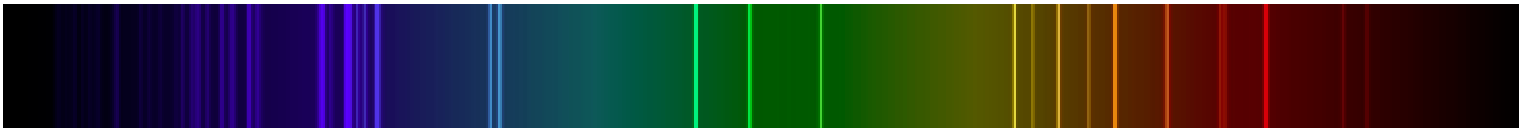4. Were the elements evenly distributed? _____

Hydrogen

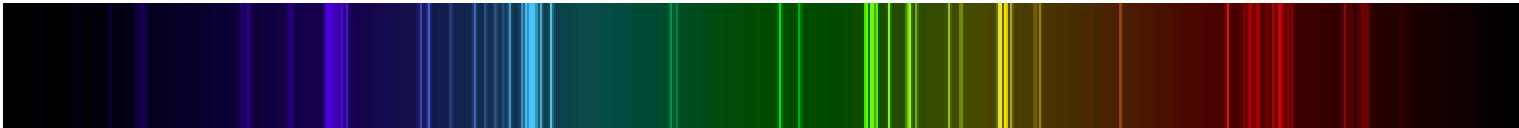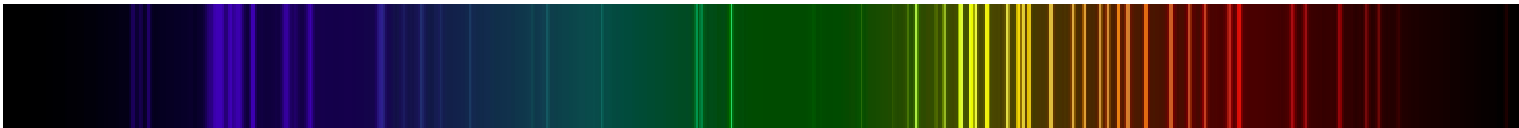# Helium

Lithium
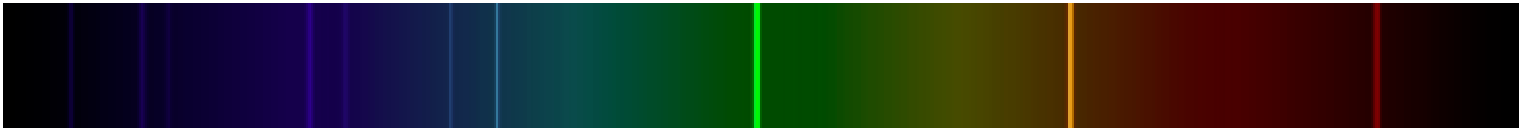
Oxygen

Carbon

Nitrogen

Neon

Magnesium